Claims

1. A device for measuring a property of living tissue, in particular a glucose level of the tissue, said device comprising

an electrode arrangement (5, 6) for application to the tissue,

a voltage-controlled oscillator (31) for generating an AC voltage (V_{VCO}) in a given frequency range to be applied to said electrode arrangement (5, 6), and

processing circuitry (37, 38) for measuring a response of the electrode arrangement (5, 6), said response depending on dielectric properties of the tissue,

wherein the voltage-controlled oscillator (31) comprises

at least one amplifier (T1, T2) having an input for a gain control signal (V2) affecting a gain of the amplifier,

at least one tank circuit (L1, D1; L2, D2) comprising at least one voltage-controlled capacitor (D1, D2) having an input for a frequency control signal (V1), said frequency control signal (V1) determining a frequency of operation of the voltage-controlled oscillator (31),

said device further being adapted to control said gain control signal (V2) for increasing the gain when the DC-voltage over said at least one voltage-controlled capacitor (D1, D2) is close to zero.

2. The device of claim 1 wherein said at least one voltage-controlled capacitor (D1, D2) is a varactor diode.

3. The device of any of the preceding claims wherein said at least one amplifier (T1, T2) is at least one dual gate FET having two gates, wherein one of the gates of the dual gate FET is connected to the gain control signal (V2).

4. The device of any of the preceding claims wherein said voltage-controlled oscillator (31) comprises two amplifiers (T1, T2), each amplifier having an amplifier output, and two tank circuits (L1, D1; L2, D2) operating at a phase shift of 180°, wherein an output voltage of said voltage-controlled oscillator (31) is derived from a voltage drop over said amplifier outputs.

5. The device of claim 4 further comprising a transformer, wherein one winding of said transformer is arranged between said amplifier outputs.

6. The device of any of the preceding claims further comprising at least one filter (C3 - C6) for suppressing AC components in the frequency control voltage and/or the gain control voltage.

7. The device of any of the preceding claims comprising a feedback loop for controlling said control signal (V2) to keep an output voltage of said voltage controlled oscillator (31) within a desired range of values.

8. The device of claim 7 wherein said device is adapted to carry out consecutive measurement cycles i and wherein said feedback loop is adapted to, in at least some of the measurement cycles i, carry out a comparison of the output voltage of the voltage controlled oscillator (31) with an optimum value ($u2_{opt}$) and to correct the control signal (V2) of a next measurement cycle i+1 depending on the result of the comparison.

9. A device for measuring a property of living tissue, in particular a glucose level of the tissue, in particular of any of the preceding claims, said device comprising

an electrode arrangement (5, 6) for application to the tissue,

a signal source (31) for generating an AC voltage (V_{VCO}) of a selectable frequency (f) in a given frequency range to be applied to said electrode arrangement (5, 6), and

processing circuitry (37, 38) for measuring a response of the electrode arrangement (5, 6), said response depending on dielectric properties of the tissue, wherein the processing circuitry (37, 38) comprises

at least one diode (D10, D11, D20, D21) for rectifying an input voltage from an input (u1, u2) and generating a rectified signal,

a filter (C10, C11, C20, C21) for smoothing the rectified signal,

an AD converter (A/D) for converting the rectified signal or a signal derived from the rectified signal to a digital value (o1, o2), wherein said digital value (o1, o2) is dependent on but not proportional to an AC amplitude (x) of the input voltage,

a processor (38) for converting the digital value (o1, o2) to a signal value substantially proportional to the AC amplitude (x) of the input voltage.

10. The device of claim 9 wherein said processor (38) is adapted to convert said digital value (o1, o2) to said signal value using calibration data.

11. The device of any of the claims 9 or 10 wherein said calibration data describes the conversion of the digital value (o1, o2) to the signal value at a plurality of different frequencies (f), wherein said processor (38) is adapted to use calibration data attributed to a current frequency of the signal source.

12. The device of any of the claims 9 to 11 wherein said calibration data describes the conversion of the digital value (o1, o2) to the signal value at a plurality of different temperatures (T), wherein said processor (38) is adapted to use calibration data attributed to a current temperature.

13. The device of any of the claims 9 to 12 comprising

a first diode (D10, D20) and a first filter C10, R10; C20, R20) for generating a first voltage depending on a minimum value of the input voltage and a

second diode (D11, D21) and a second filter (C11, R11, C21, R21) for generating a second voltage depending on a maximum value of the input voltage, and

means (A11, A21) for determining a difference between said first and said second voltage.

14. The device of claim 13 wherein said first diode is in series to said first filter and said first filter is connected to a first fixed voltage, and wherein said second diode is in series to said second filter and said second filter is connected to a second fixed voltage, said first fixed voltage being higher than said second fixed voltage.

15. The device of any of the claims 9 - 12 wherein said processing circuitry (37) comprises two inputs (u1, u2), a first input (u1) being connected to said electrode arrangement (5, 6) and a second input (u2) being connected to said AC voltage (V_{AC}).

16. A device for measuring a property of living tissue, in particular a glucose level of the tissue, in particular of any of the preceding claims, said device comprising

an electrode arrangement (5, 6) for application to the tissue,

a signal source (31) for generating an AC voltage (V_{VCO}) at a series of frequencies (f_i) in a given frequency range to be applied to said electrode arrangement (5, 6), and

processing circuitry (37, 38) comprising

measuring means for measuring a series of measurement values (m_i) at the series of frequencies (f_i), each measurement value (m_i) depending on dielectric properties of the tissue at one frequency,

fitting means for fitting a function $M(f, b_0,...,b_K)$ with parameters b_0 to b_K to the measurement values (m_i) at their given frequencies (f_i), or to values derived from the measurement values (m_i) at their given

frequencies (f_i), and determining the parameters b_0 to b_K thereby, and

means for using at least part of the parameters b_0 to b_K for determining said property.

17. The device of claim 16 wherein said processing circuitry (37, 38) comprises a measuring circuit (37) having a first input (u1) for an input value dependent on said property and on said AC voltage and a second input (u2) for an input value dependent on said AC voltage but substantially independent of said property, wherein said measurement values (m_i) are derived from a ratio between said first and said second input value.

18. The method of any one of the claims 16 or 17 wherein said function $M(f, b_0,...,b_K)$ is of the form

$$M(f, b_0,...,b_K) = b_0 + b_1 \cdot f + ... + b_3 \cdot f^R,$$

in particular with R = 3.

19. The device of any one of the claims 16 to 18, wherein said function $M(f, b_0,...,b_K)$ is of the form

$$M(f, b_0, \ldots b_K) = \sum_{k=0}^{K} b_k \cdot \chi_k(f)$$

and wherein said fitting means is adapted to store a precalculated matrix **A** and/or data derived from said precalculated matrix **A** for fitting a plurality of series of measurement values, wherein matrix $\mathbf{A} = A_{ij}$ is defined by

$$A_{ij} = \chi_j(f_i),$$

20. The device of claim 19 wherein said fitting means is adapted to store the matrix $(\mathbf{A}^T \cdot \mathbf{A})^{-1} \cdot \mathbf{A}^T$.

21. A device for measuring a property of living tissue, in particular a glucose level of the tissue, in particular of any of the preceding claims, said device comprising

an electrode arrangement (5, 6) for application to the tissue,

a signal source (31) for generating an AC voltage (V_{VCO}) in a given frequency range to be applied to said electrode arrangement (5, 6), and

processing circuitry (37, 38) for measuring a response of the electrode arrangement (5, 6), said response depending on dielectric properties of the tissue, and for converting said response to said property,

wherein said electrode arrangement comprises

a strip electrode (5) for being placed against said body,

an outer electrode (6) for being placed against said body, wherein said outer electrode comprises two lateral sections (6a, 6b) extending substantially parallel to and on opposite sides of said strip electrode (5), wherein a first (6b) of said sections is wider than a second (6a) of said sections.

22. The device of claim 21 further comprising an insulating layer (5a) covering said strip electrode (5) and at least part of said first section (6b) of said outer electrode (6).

23. The device of any of the claims 21 or 22 wherein said outer electrode (6) is annular.

24. A device for measuring a property of living tissue, in particular a glucose level of the tissue, in particular of any of the preceding claims, said device comprising

an electrode arrangement (5, 6) for application to the tissue,

a signal source (31) for generating an AC voltage (V_{VCO}) in a given frequency range to be applied to said electrode arrangement (5, 6), and

processing circuitry (37, 38) for measuring a response of the electrode arrangement (5, 6), said response depending on dielectric properties of the tissue, and for converting said response to said property,

wherein said electrode arrangement comprises

at least one electrode (5, 6) placed on an outer side of an electrically insulating substrate (4),

at least one through-contact (10, 11) extending through said substrate (4) and connecting said at least one electrode (5, 6),

wherein an outer side of each through-contact is covered by a physiologically inert material.

25. The device of claim 24 wherein the outer side of each through-contact is covered by a material selected from the group of glass, ceramics, plastics and a noble metals.

26. The device of any of the claims 24 or 25, wherein said electrode arrangement comprises at least a first electrode for being brought into direct contact with said body and wherein a surface of said first electrode consists of noble metal.

27. The device of claim 26 wherein the surface of said first electrode consists of gold.

28. The device of any of the preceding claims wherein said electrode arrangement is part of a resonant circuit, and in particular wherein a resonance frequency of the resonant circuit lies in the given frequency range.

29. The device of claim 28 wherein said electrode arrangement forms a capacitor (C) and is arranged in series to or parallel to an inductance (L), wherein said capacitor (C) and said inductance (L) form said resonant circuit.

30. The device of any of the preceding claims wherein said electrode arrangement (5, 6) is arranged on a flat substrate (4).

31. A method for measuring a property of living tissue, in particular a glucose level of the tissue, said method comprising the steps of

applying an electrode arrangement (5, 6) to the tissue,

generating an AC voltage (V_{VCO}) at a series of frequencies (f_i) in a given frequency range and applying the AC voltage to said electrode arrangement (5, 6),

measuring a series of measurement values (m_i) at the frequencies (f_i), each measurement value (m_i) depending on dielectric properties of the tissue at one frequency,

fitting a function $M(f, b_0,...,b_K)$ with parameters b_0 to b_K to the measurement values (m_i) at their frequencies (f_i), or through values derived from the measurement values (m_i) at their frequencies (f_i), and determining the parameters b_0 to b_K thereby, and

determining said property by using at least part of the parameters b_0 to b_K.

32. The method of claim 31 comprising the steps of

measuring a first input value (x_1) dependent on said property and on said AC voltage,

measuring a second input value (x_2) dependent on said AC voltage but substantially independent of said property, and

deriving said measurement values (m_i) from a ratio between said first and said second input value

33. The method of any one of the claims 31 or 32 wherein said function $M(f, b_0,...,b_K)$ is of the form

$$M(f, b_0,...,b_K) = b_0 + b_1 \cdot f + ... + b_3 \cdot f^R,$$

in particular with R = 3.

34. The method of any one of the claims 31 to 33, wherein said function $M(f, b_0,...,b_K)$ is of the form

$$M(f, b_0, ...b_K) = \sum_{k=0}^{K} b_k \cdot \chi_k(f)$$

said method comprising the steps of

storing a precalculated matrix **A** and/or data derived from said precalculated matrix **A**, wherein matrix **A** = A_{ij} is defined by $A_{ij} = \chi_j(f_i)$,

using said precalculated matrix **A** and/or said data derived from said precalculated matrix **A** for fitting a plurality of series of measurement values.

35. The method of claim 34 comprising the step of storing the matrix $(\mathbf{A}^T \cdot \mathbf{A})^{-1} \cdot \mathbf{A}^T$.